Hi We Robot!

This is a paper-in-progress—and we're really looking forward to your feedback. Thank you for being willing to engage with it and help improve it.

— Solon, Karen, and Alexandra

Reap What You Sow?
Automation, Information, and Economic Distribution on the Farm

Solon Barocas, Karen Levy, and Alexandra Mateescu

Across rural America, the day-to-day lives of farmers are changing. Traditional forms of land management are rapidly shifting into data management, as global agriculture firms such as Monsanto and John Deere have begun to furnish farm equipment with a variety of sensors that detect and transmit fine-grained information about nearly every aspect of farm conditions and operations, including soil and weather conditions, seeding and fertilizer applications, and crop yield. While monitoring and mechanization have a long history in farming, recent developments in so-called "precision agriculture" aim to move beyond a one-size-fits-all approach to customizable, plot-specific strategies.

Precision agriculture arose from the fact that productivity in a field can vary widely as a result of differences in terrain, soil, irrigation, and other conditions within and across fields. To mitigate against the unevenness of these starting conditions, precision agriculture aims to measure the exact needs of square units of land, and this information is used to develop farming strategies (called "prescriptions") tailored to these conditions on a unit-by-unit basis. Precision agriculture refers to a wide range of tools and practices, but generally comprises a combination of equipment-mounted sensors, farm data management software, and analytics services that often combine farm-level data with country-wide agronomic and weather information. Sensor-derived data is used to more closely measure agricultural productivity, to facilitate operational decision-making on the farm, and to meet the data collection standards for compliance with environmental and other regulation that requires reporting to government. These techniques also undergird ongoing efforts to further remove humans from the everyday work of farming; robots and other autonomous systems will depend just as much—if not more—on similar forms of data collection and analysis.

While adoption of such tools has been uneven, precision agriculture techniques are becoming the norm. In 2014, the American Farm Bureau Federation surveyed farmers on the issue of big data in farming, and found that more than half of respondents were planning to invest within the following year or two in additional data-driven technologies.[1] For many farmers, precision agriculture has become necessary for keeping up production and minimizing costs.[2] In particular, farmers have embraced precision agriculture as a way to improve environmental sustainability, while also increasing profits. The more precise application of fertilizer and pesticide, for example, ensures that farms do not apply more than necessary, limiting environmental impact and reducing costs. More broadly, the industry has begun to look to precision agriculture as a means to build "resilience" into food systems as climate change destabilizes centuries-old food production patterns and practices.

Many of these innovations have introduced new forms of data collection and information flow, transforming the information ecology of farming. In so doing, precision agriculture has begun to raise serious privacy concerns, with farmers expressing alarm at the prospect that a growing range of actors might have increased visibility into their farms and operations. While novel forms of data collection, aggregation, and analysis stand to improve farming and the prospect of farmers, they also run the risk of providing other actors with valuable information—information that others might use to bargain more effectively with farmers and thus claim much of the economic benefits of precision agriculture.

The farmers' case offers an important lesson for understanding the economic impacts of automation more generally. Quite commonly, we tend to conceptualize these impacts in terms of their effects on labor (the number of jobs likely to be displaced by robots, for example, and the resulting impacts on unemployed and underemployed workers). Though the labor implications of automation on the farm are cause for concern,[3] our inquiry focuses on a different set of economic impacts: the fact that automation requires new forms of information flow that can disrupt existing relationships and lead to changes in economic distribution, entirely apart from job loss.

This article proceeds as follows: In Part I, we describe the various actors involved in agricultural production and the information flows among them. In Part II, we show how these information flows put farmers in a position of economic vulnerability by allowing others to use these details to capture a greater share of the financial rewards of precision agriculture. In Part III, we describe how farmers have attempted to respond to

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[1] http://www.fb.org/newsroom/american-farm-bureau-survey-shows-big-data-use-increasing-big-questions-rem

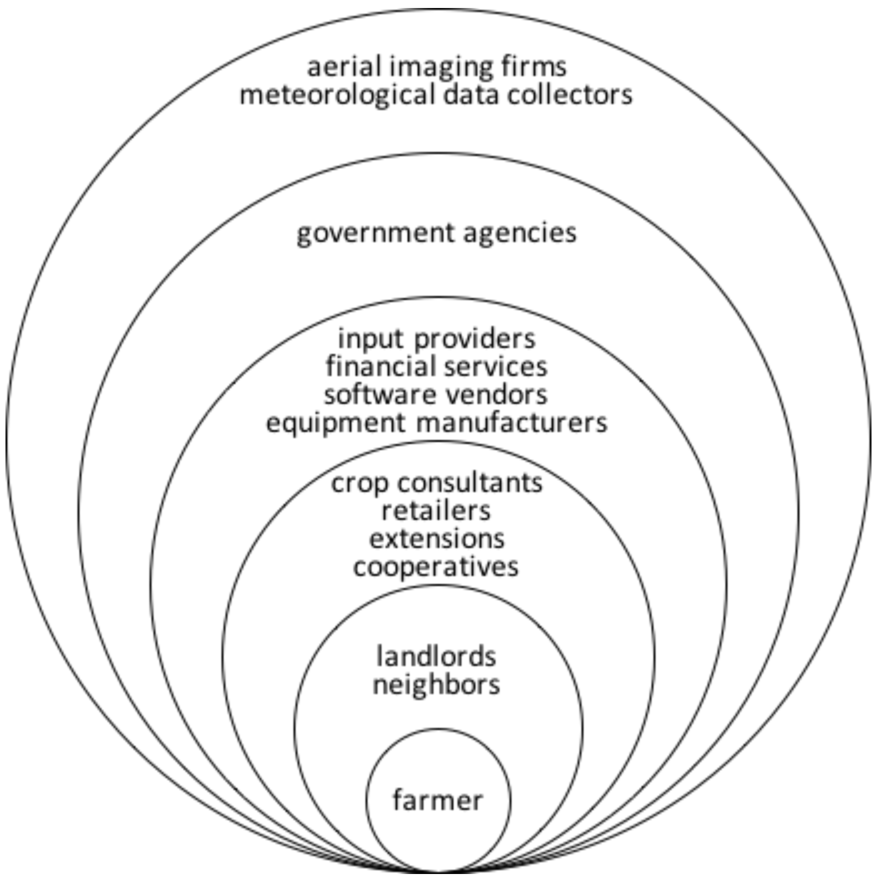
[2] This strategy is more profitable due to economies of scale in the management of large, industrial agriculture operations. To this end, large corn farms over 2,900 acres have been the most rapid adopters of precision agriculture, although smaller farms are also adopting technologies at a slower, piece-meal rate, often at greater relative costs and with less certain benefits. https://www.ers.usda.gov/webdocs/publications/err217/err-217.pdf

[3] https://www.washingtonpost.com/news/national/wp/2019/02/17/feature/inside-the-race-to-replace-farmworkers-with-robots/

these risks using privacy as a mechanism to constrain the flow of information in ways that generate a more favorable distribution.

Part I: Information Flows on the Farm

Farmers do not work in isolation; rather, they work with and among a diverse set of actors who supply inputs, equipment, advice, and more. In this section, we briefly sketch the key players in the farming ecosystem, with whom farmers commonly exchange information.



Land interests. Most immediately, farmers do their work on land adjacent to the farms of ***neighbors***. Farmers may work land that has been in their family for generations, and farm communities are often thought of as being socially close-knit. However, as we will describe in more detail later, a farmer's neighbors are also his competitors, for land and on the agricultural market. Another local player is the farm ***landlord***. About forty percent of American farmland is rented, and, as we shall see, landlords are acutely interested in information about the value that can be derived from their land.

Local offices. Farmers have ongoing and often long-standing relationships with local ***retailers*** as the go-to source for basic inputs (e.g., seed, fertilizer, etc.), provision of services (e.g., application of pesticides), and expertise; farmers are likely to share a good deal of information with their retailers in order to get the best advice and most relevant services. Retailers may also arrange test plots for customers—systematically varying farming strategies in small plots on a customer's land to determine which approach works best for the particular circumstances. Farm ***cooperatives***—organizations jointly owned by a number of local farmers, who may share equipment, pool resources to secure better prices from suppliers on inputs, and which may also offer credit and other services—often have strong relations with farmers, and may serve roles similar to those of retailers. Both retailers and cooperatives may also retain ***crop consultants*** to provide agronomic expertise. County ***extension*** offices, operated by state land-grant universities, provide related agronomic and operational advice as a component of their mission.

Corporate product, equipment, and service providers. Though retailers and other local offices often serve as intermediaries for equipment, inputs, and services, farmers may also have direct relationships with the companies that provide these. These companies include ***input providers***, including seed companies like Pioneer and Monsanto; ***software vendors*** who build precision agriculture tools; ***equipment manufacturers***, who sell farmers planters, harvesters, and other heavy equipment; and ***financial services companies***, who may provide farmers with credit and insurance. These companies are large, and commonly merge or otherwise integrate with one another. They also commonly provide more than one of these services: input suppliers and equipment manufacturers are increasingly in the business of providing subscription-based data collection and management services that enhance the material goods that make up their core products. For example, John Deere, best known as a farm equipment manufacturer, also provides credit; Monsanto, the seed conglomerate, recently bought weather data firm Climate Corporation—raising a number of concerns about data re-use for different purposes within companies.

Government. Farmers have a variety of relationships with ***government agencies***. Though this paper focuses primarily on private-sector data exchanges, farmers' information exchanges with government may inform their attitudes about data sharing with other actors, and about the economic implications thereof. The federal government provides subsidies, credit, and insurance to many farmers through a variety of programs, participation in which entails some data disclosure; in addition, farmers are encouraged (and, in some cases, required to provide information for government statistical agencies. An undercurrent of suspicion has characterized some farmers' attitudes towards government reporting to the USDA (in particular, the annual Census of

Agriculture) as well as towards participating in surveys run by the National Agricultural Statistics Service (NASS), which has seen farmers' response rates to surveys drop significantly in the last twenty years.[4] Suspicion of government bodies like the Environmental Protection Agency (EPA) is rooted in a history of controversies over perceived surveillance of farming practices and the agency's access to information deemed sensitive or confidential.[5]

Offsite data collectors. Finally, a range of newer players collect data about farmland and farm conditions remotely, and commonly without the knowledge of the farmer. ***Aerial and satellite imaging*** companies use broad-based satellite data to assess conditions and measure or predict a farmer's yield. Other companies collect detailed ***meteorological data*** which can be integrated into agronomic models.

As the range of data sources implicated in these technologies show, precision agriculture is not only reshaping farm management, but is also shifting the sources and flows of agricultural knowledge—and consequently, the relationships farmers have traditionally held with various actors and institutions.

Changes in the information ecology of farming are disrupting the delicate historical arrangements that have helped to apportion the economic rewards of farming between the many actors involved in agricultural production. Farmers have mobilized in response to these developments, demanding greater privacy, on the recognition that unconstrained information flows might harm their livelihood. Indeed, depending on the flow of information, the economic benefits of precision agriculture might not accrue exclusively or even primarily to farmers. While scholars of economics and the law have long recognized the distributional effects of privacy as a theoretical matter,[6] our paper provides some of the first empirical insights into the way privacy is put to work in practice to manage who ultimately claims more or less of the economic pie. We show that privacy mediates the many everyday economic relationships at stake in agricultural production—and that the struggle to find mechanisms to constrain information flow are proxy battles for the economic rewards of precision agriculture.

[4] See Figure 1. http://farmdocdaily.illinois.edu/2017/01/falling-response-rates-to-usda-crop-surveys.html

[5] In 2013, for example, the EPA released records of livestock farmers (including information such as home phone numbers) pursuant to a Freedom of Information Act request. Several trade associations argued that this release of records, which included information such as home addresses, blurred the boundaries between business and personal data, and rendered them targets of harassment by actors such as environmental activists. Distrust of the EPA has been further compounded by fears of the agency's access to data on management practices such as pesticide use, which could open up the possibility of increased government monitoring and regulation. See https://www.beefusa.org/newsreleases1.aspx?NewsID=2828 and http://nppc.org/epa-now-limited-on-farm-data-it-can-release/

[6] Alessandro Acquisti, Curtis Taylor, and Liad Wagman, "The Economics of Privacy," *Journal of Economic Literature* 54, no. 2 (2016): 442-92; Richard A. Posner, "The Right of Privacy," *Georgia Law Review* 12 (1977): 393-422.

Part II: Reap What You Sow?

Agricultural technologies and the data flows they facilitate may prove economically valuable to farmers, who may be able to use these analytic tools to optimize their own practices, minimize costs, and increase output; as in many other contexts, this is the heralded promise of big data. But as these technologies pervade the agricultural ecosystem, they bring with them substantial uncertainty about the relationship between data and economic value—both in terms of *how much* value is created by data collection, and *to whom* that value primarily accrues.

For their part, farmers may struggle to determine whether they are likely to realize additional value from their participation in such systems. It is often very difficult to forecast how much data-driven strategies will contribute to increased yield or reduced costs—and whether this revenue growth or cost savings will compensate for the additional expenses involved in participation.[7] Some of the reasons for such uncertainty relate to the nature of the farming enterprise. Farmers make many decisions every day, but the planting-to-harvest cycle is long; the key dependent variable—crop yield—is typically measurable only once per year, meaning that the ultimate effects of operational decisions must be assessed over a long time horizon. These assessments are further complicated by widely variable *non*-operational factors that impact yield, like weather, pest migration, and genetic mutation.[8] Therefore, tracing profits to data-driven operational decisions can be quite difficult.

Further, when data-intensive systems are in use, they are often implemented in suboptimal ways due to resource and practical constraints. Many farmers keep incomplete electronic records and may implement prescriptions imperfectly, due to time and resource stress, incompatibility of data systems, skill deficiencies, and other reasons. While prescriptions are frequently tailored to the equipment from which the relevant data has been collected, the recommended strategies may require a level of vigilance that farmers are nevertheless unable or unwilling to muster. Another significant hurdle is proper calibration of farm equipment, like planters, sprayers, and yield monitors, for the accurate measurement of data from the field. Lack of proper, regular calibration results in unreliable and incommensurate estimates that make it difficult to rely on field data—but calibration is not likely to be high on a farmer's list of work tasks. Smaller farms, in particular, face less certain returns from adopting often cost intensive

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[7] A number of studies demonstrate that precision agriculture has the potential to increase efficiency and lead to positive return on investment for farmers.
http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1051&context=ageconworkpap

[8] http://ageconsearch.umn.edu/bitstream/163351/2/20130114.pdf

data-collecting farm equipment, and may not have the resources available to mobilize data in ways that optimize yield. In a 2015 testimony to a House Agriculture Committee hearing on Big Data, the founder of the Grower Information Services Cooperative underscored the difficulty of rendering useable overwhelming amounts of data: “the data-poor environment of agriculture’s past is now data-rich, but we lack any really effective way to handle all the information that is being funneled into the agricultural producers’ management systems.”[9]

But even if precision agriculture technologies *do* create value, it is not obvious how much of that value farmers will claim. As we explain in more detail below, agricultural technology providers (ag tech providers or ATPs) and other parties stand to reap many of the potential benefits of agricultural data—and may do so in ways that ultimately harm farmers’ economic interests. The data collected by ATPs offers unprecedented and valuable knowledge about individual farms, but also the state of agriculture across entire regions and even around the world. Such data could be put to several uses, including the reshaping of commodities markets, changes in the provision of essential financial services to farmers (notably credit and insurance), and targeted marketing or discriminatory pricing of seeds and other farm inputs. The proliferation of these systems has the potential to unsettle farmers’ local relationships in the agricultural ecosystem as well. Detailed information about yield, if seen by neighbors, for example, could serve as the basis for competition over leases, driving up farmland rental rates.

In recognition of these concerns, farmers have begun to assert privacy interests in data about their land and operations. An American Farm Bureau Federation survey in 2016 found that 77 percent of farmers were “concerned” or “extremely concerned” about what actors have access to data generated through precision technologies, and 61 percent expressed concern over companies’ uses of data to influence farmers’ market decision-making.[10] But these concerns are often asserted—and, as we shall discuss, privacy-protecting measures deployed—without specific delineation of *what*, precisely, farmers are ultimately concerned about.

Here, we attempt to specify the economic risks of precision agriculture at three levels, each of which seems to underlie farmers’ call for greater privacy. First, we consider the systematic harms of data collection, in which markets may be manipulated based on ATPs’ aggregation of millions of acres’ worth of farm data. Second, we consider risks related to market power, in which ATPs have access to many types of farmers’ data, and may triangulate among these types of data to deepen information asymmetries, price discriminate on inputs, and otherwise use data in ways unanticipated by farmers.

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[9] http://agriculture.house.gov/uploadedfiles/10.28.15_tiller_testimony.pdf
[10] https://www.agri-pulse.com/articles/6969-farmers-want-control-of-ag-data-survey-shows

Finally, we consider the harms in farmers' local communities—that is, the ways in which data collection can create risks for farmers vis-a-vis their neighbors and landlords.

Cross-farm data aggregation and market manipulation. One set of concerns involves the use of data aggregated across many farms to manipulate futures markets. Commodities traders stand to profit from accurate, real time, dynamic predictions of aggregate crop yields. Historically, traders have typically relied on more static information such as USDA-sourced yield data, which are made available publicly at the same time to all players. However, a significant competitive advantage could be wrought from access to real-time data collected by digital monitors on farm equipment, aggregated across millions of acres of farmland.[11] In this way, farm data might create significant financial value—but it is unlikely that that value would accrue to the individual farmer. And it might even decrease farmers' profits, if data-informed traders depress the prices of farmers' futures contracts.[12]

Cross-activity data aggregation and market power. In addition to concerns about the aggregation of farmers' data across millions of acres, other key privacy concerns relate to the aggregation of data across farmers' various *activities*.[13] As mentioned, precision agriculture firms are rapidly merging with, and being acquired by, other large players in the agricultural marketplace: seed companies, equipment manufacturers, agronomic software developers, and credit providers are rapidly integrating. While such integration and service bundling offers some potential advantages for farmers (for instance, easier interoperability of systems), it also creates risks.

Financial services. Farmers are concerned that financial service companies may gain access to or demand granular information about their farms and operations, making credit and insurance more difficult to obtain or to secure at a favorable rate.

***Price discrimination*.** Similar information could empower the various actors from whom farmers must buy inputs, equipment, and services to target their marketing much more effectively and to price discriminate. Farmers fear being manipulated by marketing backed by a rich dossier of information. And should these actors be able to estimate farmers' willingness to pay on the basis of this information, farmers could end up giving away all of the economic surplus.

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[11] http://the-magazine.org/43/data-harvesting
[12] Jacob Bunge, "Big Data Comes to the Farm, Sowing Mistrust," Wall Street Journal, February 25, 2014, http://www.wsj.com/articles/SB10001424052702304450904579369283869192124
[13] [really, both are at play here -- things like price discrimination are made possible based on aggregation of multiple farmers' data, not just one farmer's activities]

Lock-in. Farmers frequently worry about their dependency on a small handful of input and service providers, especially those companies that have begun to provide both. If the company providing data-driven recommendation is also a seed supplier, for example, farmers fear that they may have little choice but to purchase the seeds that go along with the prescription.[14] Especially worrisome are situations in which companies provide services and inputs as a discounted bundle, rendering alternative arrangements even less viable.

Digital rights management. Manufacturers of precision agriculture hardware and software may also limit the degree to which farmers can port data collected with these devices or tinker with the underlying technology, even in cases where farmers might want to repair broken or malfunctioning equipment.

Data leakage and local competition. The proliferation of data-gathering systems has the potential to disrupt not only farmers' traditional work practices and relationships with ATPs, but also to unsettle farmers' *local relationships* with other actors in the agricultural ecosystem. Farming is not a solitary profession; farmers' work stands in close relation to a wide variety of other parties—neighbors, landlords, crop consultants, ag retailers—with whom they exchange information. Such information exchange has often taken place in relatively informal and general terms, and based largely on long-term trust, loyalty, and sensitivity to social norms. Yet farmers have strong interests in preventing neighbors from learning *too* much about their operations. A 2016 study on attitudes towards information sharing found that Nebraskan farmers felt most comfortable sharing their information with university researchers/educators (44%) or local cooperatives (43%), while only 13% of farmer respondents said they would be comfortable with sharing their data with their neighbors. 22% of respondents claimed they wouldn't be comfortable sharing their information with anyone.[15]

The uneven benefits of aggregation. While ostensibly one of the main selling points of precision agricultural tools that aggregate data across many farms, the insights derived from the aggregated data might be more or less useful for different farmers that participate in the system. A farmer could find that he receives recommendations that are very much in line with what he has been doing already, validating his strategy. At the same time, though, a neighboring farmer who had been struggling to achieve comparable success might receive the same recommendation—a strategy that company learned from the neighbor's experience. Some companies make this an explicit part of their pitch: providing aggregated—and therefore anonymized—data that

[14] http://the-magazine.org/43/data-harvesting
[15] See Table 3, Castle et al, "Factors Influencing Producer Propensity for Data Sharing & Opinions Regarding Precision Agriculture and Big Farm Data" http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1051&context=ageconworkpap

tells farmers what members of their local community are doing and what strategy has been most successful in the region.[16] This may come as a threatening or attractive offer, depending on the farmer's expected benefit from participation. If increased supply risks depressing prices, farmers may have good reason to worry about contributing to their neighbors' improved success. Additional yield can't compensate for lower prices when farmers were already close to optimal yield. And even if a neighbor's improved success does not threaten a farmer's ability to cash in on his strategy in the future, he may bristle at the idea that his hard-earned insight has been shared with his undeserving neighbor.

***Competition among neighbors*.** As more data are gathered about a farm's performance over time, these data can be marshaled to increase competition among farmers for tracts of land. Farmers frequently seek to increase revenue by acquiring more land to farm; because they have already invested a substantial amount of money in the fixed costs of equipment and the like, increasing the size of the farm is likely to result in positive returns on investment without much additional outlay—a case of economies of scale. The farmland purchase and rental[17] markets are, therefore, quite competitive. Data collection can augment this competition in three ways.

First, more consistently captured and more precise data can increase direct competition among farmers for rental of a particular field. Farmers often have a general sense of a neighboring farm's productivity—because farming occurs in open fields, farmers can easily peek in on a neighbor's farm to get a sense for crop yields. However, it is more difficult for farmers to glean information about the *inputs* neighboring farmers apply to achieve such a yield—how much fertilizer they apply and the like—making it impossible for them to glean that farmer's return on investment (ROI). However, data-intensive systems provide both more precise information about yield *and* information about treatments and inputs; therefore, anyone with access to this information has a much better sense for the true ROI of a farmer's operations.

If a farmer is equipped with information about a neighbor's ROI, he may attempt to use that information to rent land out from under his neighbor; that is, the farmer may contact the neighbor's landlord and offer to pay a higher rent for the land, knowing that the neighbor's land can generate enough revenue to cover the increased cost.[18] Such negotiations can be rather delicate, though, as the farmer does not want to communicate how valuable he perceives the land to be—only that he is willing to pay

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[16] http://the-magazine.org/43/data-harvesting
[17] About 40 percent of U.S. farmland is rented.
https://www.agcensus.usda.gov/Publications/2012/Online_Resources/Highlights/TOTAL/TOTAL_Highlights.pdf
[18] https://www.everycrsreport.com/reports/R44331.html

more for it than his neighbor. A landlord may realize that such offers signal that the land is mis-priced and therefore raise rents to more closely match its true underlying value, which may be higher than the farmer's initial offers designed to steal land away from his neighbor. Even in the absence of competitive bids from farmers of adjacent land, landlords might attempt to learn about their tenants' profitability, with the goal of setting rents more in line with their land's ability to generate revenue and what the rental market will bear. At the extreme, some landlords may include terms in lease agreements that require tenants to share data collected on their property.[19]

Fierce competition over rental properties—spurred by a more precise sense of land's capacity to generate a profit—therefore risks washing away the economic benefits of precision agriculture for farmers if rent increases perfectly in line with or close to the technologies' ability to increase revenue. In other words, by increasing rents, landlords can claim a share—or potentially all—of the economic surplus that farmers might gain from the adoption of precision agriculture.

Land valuation. Second, a "data layer" about a particular field can become a new kind of asset attached to the land, the presence of which may increase its value. Several farm real estate database companies are integrating more data into their land valuation tools; for example, the farm management software company Granular also owns AcreValue, a platform that generates estimated valuations for particular tracts of land based on data about crop history, soil type, and other factors.[20] As it becomes more common for a unit of land to have an extensively documented yield history, farmland valuation can therefore integrate data about a land's historical productivity—but in addition, the mere *existence* of such data can increase the land's worth.

This matters for competition because farmers may become willing to pay higher rates for "data-endowed" land[21]—and conversely, an absence of extensive records may put farmers at a disadvantage, garnering a potential penalty if there is little available data to transfer with a land sale, and providing an additional incentive for participating in data systems so as not to be left behind.[22] An implication of this is that the availability of data from adjacent or local farmland may be of value to a farmer in possession of inadequate data from their own land. Some speculate that, as extensive data histories become more common, farmers may be incentivized to pay a premium to obtain adjacent

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[19] https://www.linkedin.com/pulse/addressing-big-data-farm-leases-todd-janzen
[20] http://www.precisionag.com/systems-management/data/granular-expands-acrevalue-farmland-analysis-site/
[21] https://www.linkedin.com/pulse/big-data-impact-farmland-values-rental-rates-terry-griffin
[22] http://www.agmanager.info/crops/prodecon/precision/PrecisionAgData_FarmlandValues.pdf

farmland that includes a data layer.[23] Given this new dependence of farmland value upon data, farmers may have incentive to become more guarded about who has access to their data on a local level.

Changing roles for retailers, consultants, and extensions. Even as farm management has become increasingly data-driven, consultation services provided by retailers, agronomists, and extensions continue to play a significant role in providing professional advice. A 2014 report from the Iowa State University Extension and Outreach, for example, found that more than 60% of farmers surveyed depended at least partly on professional advisors for decision-making across a variety of areas.[24] But new types of data and data flows have begun to put pressure on these actors in two very different ways.

First, intermediaries like retailers find themselves with far more granular information about their customers' farms than in years past—information that farmers may expect retailers to protect ever more vigilantly as a consequence. Farmers have long had to trust outside companies with sensitive information as a condition of employing their services. For example, a local retailer might learn quite a bit about a farm when contracted to develop or apply a pesticide prescription, and the retailer could choose to share this information with a competitor farmer in order to secure his continued business. Farmers' willingness to share details of their operations with retailers has always required some degree of trust, but the advent of precision agriculture has begun to put strain on the traditional mechanisms by which farmers established and maintained confidential relationships. These intermediaries are increasingly placed in more formal roles as agricultural data stewards. This is especially true when a remote data platform may not lend themselves to the kinds of reputational harm and social sanction that previously prevented local parties from violating one another's trust.

At the same time, however, intermediary roles traditionally played by retailers, local cooperatives, crop consultants, agronomists, and extensions are being absorbed in part by off-site analytic services that are provided by corporate actors, often as additional services to the application of agricultural inputs such as pesticides. In relying upon and promoting the use of new technologies, these actors may be undermining their own value to farmers. Retailers run the very serious risk of participating in their own replacement by third party software vendors.[25] Concomitantly, public funding for agricultural research has been in decline since the 1980s, while privatized research through corporate channels has grown. This has begun to raise questions about the

[23] http://www.agview.net/articles/features/2015-04-06-precision-agriculture-data-impact-on-farmland-values-big-data-in-ag
[24] https://store.extension.iastate.edu/Product/Iowa-Farm-and-Rural-Life-Poll-2014-Summary-Report
[25] http://ageconsearch.umn.edu/bitstream/240696/2/320150137.pdf

proprietary nature of data, particularly in cases where private research is dependent on data derived from farmers using a company's products.

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Taken together, the perceived risks of unconstrained information flow in farming are myriad—and they all have to do with economic distribution. In some cases, the data collection necessary for precision agriculture reduces uncertainties that previously offered farmers some degree of protection from the vagaries of agricultural production—allowing firms to make more informed bets in financial markets or more accurate predictions about credit default or insurance claims. Such actions may limit farmers' ability to rely on these mechanisms to reduce their economic exposure, displacing risk—and associated costs—onto individual farmers. In other cases, precision agriculture seems to undo information asymmetries that previously favored the farmer—helping vendors, for example, better estimate how much farmers value certain goods and services and charging customers accordingly. In so doing, these actors can claim more, if not all, of the economic surplus that farmers might have enjoyed from prices set below their willingness to pay. In the case of land value, data can wash away the benefits that farmers may have enjoyed from rents that were not perfectly tied to land's apparent productive capacity—effectively transferring the economic benefits derived from precision agriculture from farmers to landlords. The move toward precision agriculture can also empower dominant market actors, who may attempt to lock customers into tightly integrated offerings, limit interoperability, and create platforms that can serve as a unified clearinghouse for data. These actions will invariably reduce competition and allow firms to extract rents from their clients. They may also facilitate disintermediation by allowing vendors to interact directly with farmers, circumventing the retailers and co-ops upon whom farmers previously relied for supplies and services. Indeed, retailers and co-ops may find that they have little choice but to provide data-driven services to customers and members that render their offerings far less valuable—transferring local knowledge and income to distant and disembodied firms.

Even when farmers might enjoy a collective benefit from sharing their individual data—discovering prescriptions, for example, that work well under different circumstances—individual farmers may hesitate to participate if doing so runs the risk of helping competitors or suppressing prices by flooding the market. In this case, farmers would redistribute the benefits of agricultural production among *themselves*—smoothing out the degree to which different farmers are able to profit from the enterprise. In other words, even if knowledge pooling benefits farmers as a whole, those farmers who previously outperformed their peers may not welcome the equalizing effect on the distribution of benefits. And increased overall productivity in farming could also mean that farmers have more to sell, but end up making less from each sale. Increased revenue might not mean increased profits because the benefits of increased productivity on the farm might go to customers who instead enjoy lower prices at the supermarket.

Part III: Privacy as a mechanism for redistributing benefits

So far, we have explored the potential distributional effects of precision agriculture with a specific focus on farmers' economic interests. Our goal here is not to advocate in favor of farmers' interests or to argue that farmers have a natural or exclusive claim to the economic benefits derived from the technology; rather, we aim to account for the potential impact on farmers to better explain their critical posture. Ours is primarily a descriptive account of the distributional effects and the reactions they engender, not a normative one.

To be clear, there are many important reasons to care about the distributional effects of precision agriculture. Different normative or economic principles might counsel in favor of different distributions. Most immediately, if new technologies stand ready to improve productivity, increase efficiency, reduce environmental impact, and enhance society's overall welfare, we should worry if distributional concerns impede adoption. If we fail to attend to concerns about the distribution of benefits, there might be no benefits to distribute.

We might also care about the distribution of benefits if we want to incentivize innovation and productive investment. When unconstrained information flows foster competition among farmers over land, landlords are the ones who benefit—even though landlords have done nothing to contribute to increased productivity. In other words, landlords are able to claim the benefits when others discover how to make more effective use of the land. Such distributions do not reward the ingenuity that we might want to promote.

And while farmers are not unequivocally entitled to reap the rewards of precision agriculture, we might nevertheless worry about arrangements that contribute to economic inequality. To the extent that novel information flows allow other actors to claim more of the rewards from agricultural production, farmers may find themselves worse off economically than the many companies on which they rely. This may make it even more difficult for farmers to organize effectively to counter the increased power that accompanies this transfer of wealth. At the extreme, market power may allow certain actors to limit competition and extract rents—not only claiming the true economic benefits of precision agriculture, but artificially inflating prices to further burden customers.

At the same time, we might want to foster competition if consumers end up paying lower prices for the same goods as a consequence. Likewise, farmers might be perfectly happy to transact directly with suppliers rather than working with local retailers if farmers are able to pay lower prices.

We stake no claim as to which particular distribution of benefits is normatively desirable. Rather, we consider how farmers have mobilized around privacy to argue for their own economic interests. What we observe in farming is a roundabout attempt to protect farmers' economic interests by devising mechanisms to regulate data collection, aggregation, and use. In the remainder of this section, we will describe three primary responses: (1) transparency; (2) data ownership; and (3) data cooperatives. In describing each of these developments, we will also explore how well these proposals map to the specific practical and normative concerns described above. In particular, we will reflect on how well these mechanisms are likely to generate a more favorable distribution for the actors championing their adoption and use.

Transparency tools. One of the more widely publicized policy responses to date focuses on the terms of the contractual relationship between farmers and ATPs. The Agricultural Data Transparency Evaluator is a tool developed by an agricultural law firm in partnership with the American Farm Bureau Federation. The Transparency Evaluator requires participating companies to respond to a set of ten questions about how they will treat farmers' data: what sorts of data they collect, third-party sharing policies, retention, etc. After the companies' answers are verified by a third party, those that qualify are awarded a seal of approval aimed at helping farmers make decisions about entering into contracts with the ATP.[26]

1. What categories of data does the product or service collect from me (the farmer)?
2. Do the Ag Technology Provider's (ATP's) agreements address ownership of my data after my data is transferred to the ATP?
3. If the ATP contracts with other companies to provide data related services, does the ATP require these companies to adhere to the ATP's privacy policies with me?
4. Will the ATP obtain my consent before providing other companies with access to my data?
5. After I upload data to the ATP, will it be possible to retrieve my original complete dataset in an original or equivalent format?
6. Will the ATP notify me when its agreements change?
7. Will the ATP notify me if a breach of data security occurs that causes disclosure of my data to an outside party?
8. Upon my request, can my original dataset be deleted when my contract with the ATP terminates?
9. Do the ATP's agreements establish how long my original datasets will be retained?

[26] http://www.aglaw.us/agdatatransparent/

10. Do the ATP's agreements address what happens to my data if the ATP is sold to another company?

Questions comprising the Ag Data Transparency Evaluator (source: https://www.agdatatransparent.com/).

The Transparency Evaluator occupies familiar territory for privacy researchers, as it sits alongside a number of similar tools in other domains designed to make privacy policies more legible to users.[27] The Evaluator is relatively agnostic as to the *content* of ATPs' data policies; rather, its focus is on the disclosure of whatever those terms happen to be. The goal of the tool is to provide more informative notice to farmers so that they can more readily evaluate policy terms before entering into an agreement—and on the other side, to incentivize ATPs to disclose information about key data practices (and perhaps to compete with one another to offer more favorable terms to farmers, since those terms will be easily comparable across providers).

To be sure, there may be some value in providing meaningful notice of the content of these agreements to farmers, so that they can be empowered to make more informed choices. But the empirical evidence demonstrating the effectiveness of such tools is mixed, at best.[28] And any value is further undercut by the realities of the ATP marketplace, in which a small number of large ATPs (like John Deere or Climate Corporation, which have backed the nonprofit Transparency Evaluator) have dominant market share. These companies' privacy policies are contracts of adhesion, the terms of which farmers have no ability to negotiate. And privacy protections that rely on contract transparency fall victim to the spate of arguments against notice-and-choice regimes' utility at granting users meaningful control over their data.[29]

This approach frames the problem as a *lack of information* among farmers about ATPs' data practices, and presumes that if farmers are better informed, they will be better able to negotiate effectively for their interests. The way to reverse any undesirable distribution of benefits is to ensure that farmers are equipped to bargain for a more desirable distribution, or comparison-shop among providers in search of one. Notably, the Evaluator does not set down specific prohibitions on ATPs data practices; it merely requires that they disclose their practices.

Hi again We Robot! Our paper is not *quite* finished, but here we will say something like:

[27] For a review: "Trustworthy Privacy Indicators: Grades, Labels, Certifications, and Dashboards," Reidenberg et al, Wash U Law Rev. See also: http://solon.barocas.org/?page_id=200
[28] Calo, Against Notice Skepticism in Privacy (and Elsewhere) ("Studies show only marginal improvement in consumer understanding where privacy policies get expressed as tables, icons, or labels, assuming the consumer even reads them.")
[29] Solove, Privacy Self-Management and the Consent Dilemma

There are two other primary tools farmers are trying to develop:

Data ownership. Some people have turned to a conception of privacy *as data ownership*, arguing that farmers (a) should be explicitly recognized as the owners of data derived from their farms; and (b) should be able to make an ensuing property claim that entitles them to be compensated for use of their data by ATPs. It has become common for ATPs to assert that they respect farmers' privacy and that "farmers own their data," often without any real explanation about what this means or entitles the farmer to.

We'll suggest that data ownership appeals to farmers for a diverse set of reasons, but specifically because it means that farmers can claim a share of the economic benefit that others might derive from their data—limiting others' ability to claim these benefits for themselves.

Data cooperatives. Farm data cooperatives are positioning themselves as the farmer-friendly intermediaries to safely and profitably share, sell, and store farm data. Cooperatives aggregate farmers' data, which can then be analyzed and the results shared with member farmers—or, it can be anonymized and sold to interested third parties. Data cooperatives are appealing to farmers because they are able to reap some of the benefits of scale, aggregation, and knowledge-pooling, without having to depend on ATPs with their own financial interests. Cooperatives can also negotiate on behalf of their members, extracting better rates from buyers than any farmer might be able to individually.

We could use some help thinking about how to connect our analysis of information flows (Part II) with our analysis of these responses (Part III). It seems obvious to us that these proposals are an incomplete response to the problems we discuss in Part II, but we'd like to say more than that. We'd love some help thinking through the lessons to be drawn from the limitations of these proposals, and what they tell us about the use of privacy as a mechanism for effecting a desirable economic distribution.

Thank you!

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